HOW TO ISOLATE THE DEFECTIVE SECTION AND STAGE

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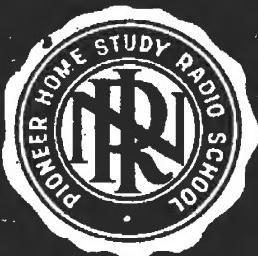
Study Schedule No. 37

For each study step, read the assigned pages first at your usual speed. Reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ **1. Inspection for Surface Defects** - - - - - - - - - **Pages 1-6**

Simple defects outside a receiver chassis occur often enough to make a quick inspection for surface defects highly desirable. It is important to realize that the actual inspection takes only a few minutes, far less than the time it takes to read this section. Once you've worked on a few receivers, you'll find that this quick external inspection of a radio set becomes second nature to you.

☐ **2. Effect-to-Cause Reasoning** - - - - - - - - - - **Pages 6-12**

Here are practical examples to illustrate exactly how effect-to-cause reasoning can bring you directly to the defective stage or part, thereby saving considerable time. Reasoning admittedly will not always work; in fact, the important thing for you to realize in connection with this section is that you should be ready to give up reasoning and start isolation procedures unless some very definite clues exist.

☐ **3. Defective Section and Stage Isolation** - - - - - - **Pages 12-19**

This section is a general survey of the different isolation techniques which may be used to isolate a defective section or stage. Therefore, it is not intended to teach you exactly how to carry out isolation techniques for particular complaints. These instructions will come later.

☐ **4. Test Equipment for Signal Tracing** - - - - - - - - **Pages 19-23**

Basic circuits and general operating principles of four different kinds of special servicing instruments are given in this section. Here you learn enough about signal tracing instruments to be able to quickly put to use any of this equipment you may encounter.

☐ **5. Isolation Techniques for a Dead Receiver** - - - - - **Pages 24-28**

Here you receive detailed instructions for applying different isolation techniques to a dead receiver. The choice of techniques depends upon personal preferences as well as on the instruments you have available.

☐ **6. Answer the Lesson Questions, and Mail your Answers to N.R.I.**

☐ **7. Start Studying the Next Lesson.**

Inspection for Surface Defects

A PROFESSIONAL serviceman is concerned with two vital points: first, to find the defect; and second, to find the defect as quickly as possible. There are many ways of locating a defect, but only a carefully planned procedure will lead to the cause of the trouble in a direct, quick manner.

Never lose sight of the fact that a serviceman is selling time. If you can shorten the time consumed on any repair job, you can handle more jobs and have more time to plan your business and to advance yourself. It is important, therefore, that you learn the basic procedure for localizing trouble. This straightforward procedure of isolating the defective section, stage, circuit and part can be followed even by a serviceman with little experience and will save time, compared to guess-and-try methods.

Before studying the defective section and stage isolation procedures, we should complete the four preliminary steps of the technique shown in Fig. 1. These preliminary steps may lead you directly to the trouble. If they fail to do so, they will at least indicate the correct isolating method for the particular complaint, thus making other tests unnecessary.

We have already covered the first two steps, so we can now concentrate on steps 3 and 4. In this lesson we are going to study step 4 before step 3, because the inspection for surface defects will, in many instances, follow the confirmation of the complaint or may become a part of the effect-to-

cause reasoning process, as you will learn shortly.

Logically, we should go over the external connections to the radio and as much of the top of the chassis as possible before removing the chassis from the cabinet. However, in the case of midget receivers, it may be necessary to remove the chassis from the cabinet
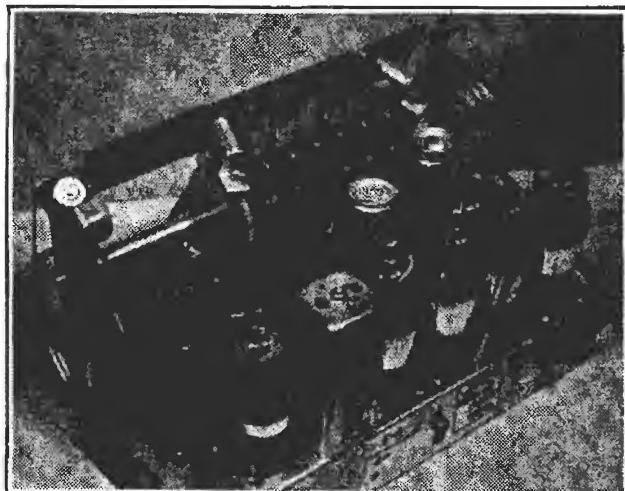
Courtesy Philco

A surprising number of complaints are caused by defects on the surface of a radio. Watch for such items as defective tubes, tubes in the wrong socket, top cap connections loose or broken, defective speaker or antenna and ground leads, etc. Each complaint will have its own list of possible defects.

before a complete inspection can be made.

Remember that we are trying to save time. Therefore, concentrate on those surface defects which could cause the complaint, instead of making a minute examination of everything. We have divided the following discussion into steps, according to the ten common complaints, so that you can become familiar with the symp-

toms caused by different surface defects.

If you do not find the trouble in a few moments, when checking for surface defects, go on to the next step in the service procedure.

1. Dead Receiver. If the pilot lamp does not glow and if none of the tubes heat up, first make sure that the receiver is getting power. See if the power cord plug is in the wall outlet, and inspect the plug. Feel along the length of the power cord to see if there is a break. The wall outlet may be defective or may not be getting power; if you suspect this, check voltage at the outlet with a meter or by plugging a floor lamp into the outlet. Wiggle the plug in the outlet, as it may not be making contact.

A burned-out tube is a common trouble which can cause a dead receiver, so look for a cold tube or one in which the filament does not glow. If all tubes are cold and the set is of the universal a.c.-d.c. type, check all tubes in a tube tester, because the tube filaments are connected in series and an open in any one of them will block filament current to all tubes.

If the tubes light or heat up, look for a disconnected tube top-cap connection, inspect the loudspeaker leads, the loudspeaker plug or terminal connections, and the antenna and ground connections. Look particularly for an open voice coil lead if the set is completely dead (no hissing, hum or other sound from the loudspeaker). If there are any special switches at the back of the chassis, see if they are set correctly.

• Be sure the power source is of the correct type for the receiver. There are still a number of 110-volt d.c. homes in large cities, and a.c. receivers will not work in these; in fact, the power transformer will burn out if an a.c. receiver is plugged into a d.c. outlet. Furthermore, with universal
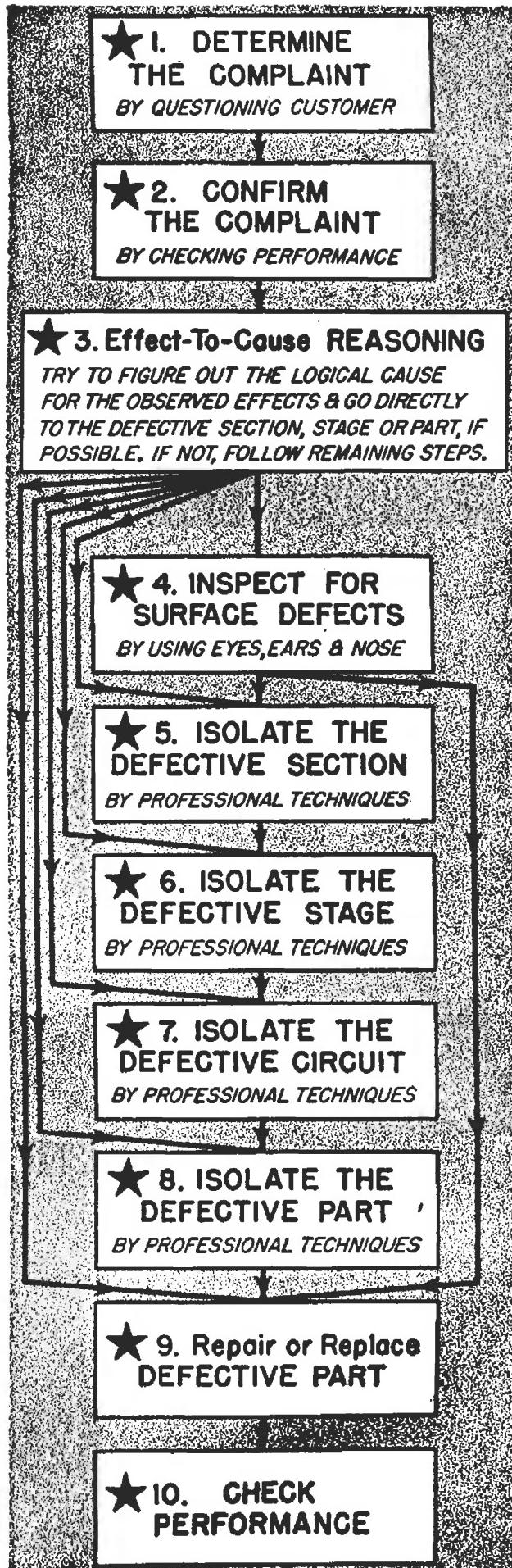
FIG. 1. The complete professional servicing procedure for radio receivers.

a.c.-d.c. receivers and d.c. receivers, the power cord plug must be inserted with the correct polarity to secure satisfactory d.c. operation; try reversing the plug if you encounter this situation.

With battery receivers, check the condition of all batteries and check all battery connections, because failure of any battery or any battery connection can definitely cause a dead receiver.

2. Noisy Reception. First determine whether the noise is originating inside the receiver chassis, outside the chassis but in some part of the receiver installation, or entirely apart from the receiver installation.

Disconnect both the antenna and ground leads, and short together the antenna and ground terminals of the receiver; if the noise now stops or is greatly reduced, there is an external noise source or the antenna-ground system is at fault. If the noise does not change appreciably, the trouble is in the receiver itself or the noise is coming in through the power line.

In the case of a set having a built-in loop antenna, rotate the loop or rotate the entire cabinet to secure the same effect; if this causes a change in the amount of noise, the trouble is external.

Noise may originate in the power line system and enter the receiver through the power cord. If a line noise filter is available, it can be inserted in the wall outlet, and the receiver plugged into the noise filter to block any noise signals coming in over this path.

If the noise starts or stops when a house light or other appliance in the house is turned on or off, the noise is definitely localized to a defective lamp, switch or appliance. If the noise occurs when someone walks across a room in the house, pipes in the plumbing system may be rubbing together, or the receiver power plug may be making a poor contact in the wall outlet. Check by wiggling the power cord and plug. If the noise increases, examine the plug for broken wires, bend the prongs to make better contact, or replace the plug. Be particularly suspicious of any cube tap (three-outlet plug-in device). Try plugging the radio into another outlet, using an extension cord if necessary.

If the noise source is outside the set, check the antenna and ground leads by reconnecting them to the set.
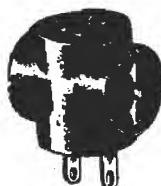
This cube tap is a common source of noise. Poor contacts develop in these devices.

With the set turned on, shake these leads vigorously. If this increases the noise, look for a poor connection or break.

If noise is localized to the receiver, tap each tube while the receiver is in operation. Again, an increase in the noise level indicates that the trouble has been located. Be on the lookout for top-cap connections which are loose or touching the tube shields. Don't be misled by this test, however. Sometimes tapping a tube may jar the actual defective part or terminal and thus lead you to believe the tube is defective. If a new tube acts the same way, you have an under-the-chassis defect.

Variable condenser plates just barely shorting together may cause noise. This condenser trouble can quickly be identified, as the noise will be intensified when you move the rotor plates as you tune the receiver.

A loose cone or loose turns on the voice coil of the loudspeaker may produce a combination of noise and distortion, which can be recognized after

being heard a few times. Remember to notice such combination symptoms, as they frequently lead you right to the trouble.

3. Annoying Hum. There are quite a few causes of hum which are external to the chassis. Thus, a poor ground connection may permit the receiver chassis to pick up stray ripple fields. The resulting hum current in the chassis can enter a grid circuit and cause hum. Check the ground lead and the ground connection for this trouble. Try reversing the power cord plug in the wall outlet, because many sets are grounded through the power line.

Tubes in the a.f. stages with cathode-to-heater leakage can cause hum when the cathode is not directly connected to the chassis. Check the tubes for leakage in a tube tester.

Rectifier tubes are sometimes causes of hum. If the rectifier tube is of a vacuum type and has a purplish-blue glow between the elements, gas exists in the tube and is preventing normal rectification. When a gassy rectifier tube is found, remember that the gas condition may be the result of excessive current flow through the tube. The filter condensers should be checked, as excessive leakage will result in high rectifier current.

You will sometimes notice a white salt-like deposit on the cap of electrolytic condensers. This indicates the escape of some of the electrolyte. When the complaint is hum, these condensers should be checked.

Watch out for a line cord tucked into the set next to a grid circuit lead; pull out the cord to see if this reduces the hum.

4. Howling. In general, squealing (or howling) is due to electrical or mechanical coupling between circuits. A missing shield can cause this condition. Excessively long antenna and ground leads are sometimes jammed into the cabinet and there cause coupling between stages, resulting in squealing. Shortening the leads is the remedy.

Howling can occur when some part vibrates under the influence of sound waves from the loudspeaker. Tubes made about ten years ago lacked internal bracing of electrodes, and hence were particularly subject to microphonic trouble of this nature. Touching a microphonic tube will usually identify it as the offender by stopping the acoustic feedback. Replacing the microphonic tube with a more modern tube of the same type, having a more rigid internal construction, will usually clear up the trouble.

Microphonic trouble may occur in the input audio stage of any high-gain audio amplifier, even with modern tubes. Try several tubes to find one which is less troublesome. Save the other tubes for use in a less critical stage.

If the rubber supports under the chassis of a receiver become hard, mechanical feedback from the speaker, through the cabinet will cause howling. Likewise, if the shipping bolts were not removed or loosened when the receiver was installed in the home, there will be mechanical coupling from the chassis to the cabinet through these bolts.

Front-panel control shafts should not touch the sides of the cabinet holes, and control knobs should be a short distance away from the panel. Felt washers are often used between the knobs and the panel to minimize chances for mechanical feedback which can cause howling.

Mechanical vibration of the rotor plates on gang tuning condensers will cause a howl, as this changes the capacity at an audio rate. Rubber mountings are usually used under the condensers to prevent this; be sure they have not hardened.

5. Distortion. As a general rule, it is a good idea to check all tubes in a tube tester when the complaint is distortion. A low-emission a.f. tube is a possible cause of distortion, because it changes the shape of the E_g-I_p characteristic curve. Strong signals then swing over a non-linear portion of the curve.

The use of an excessively long antenna on certain midget receivers may give an input signal so high that the receiver circuits are overloaded and distortion results. Hence, if you find that a midget receiver distorts on strong local stations but gives normal reception for weak locals and distant stations, try shortening the antenna.

A boomy, distorted tone can occur when a set is placed right up against a wall. Moving the set about two inches away from the wall will eliminate this trouble.

Defective loudspeakers are another common cause of distortion. Once you've learned to recognize the effects of loose turns on the voice coil, off-center voice coils, excessively hard or excessively soft cones, broken spiders, etc., you will be able to recognize these troubles when checking performance.

6. Low Volume. As you know, an audio system defect is indicated when both distant and local stations are heard but volume is low. Check the a.f. and detector tubes in your tube tester before going on with the service procedure, as a low-emission tube may be the trouble.

Be on the lookout for a phono-radio switch set in the phono position, particularly when the switch is on the rear of the set or on the phonograph mounting board. The set owner will usually turn the knobs on the front of a set but will frequently overlook others.

7. Poor Sensitivity. Unsatisfactory reception of distant stations can be due to a defective pickup system, hence the antenna and ground should be checked thoroughly if this is the complaint. Tune in a local station, then disconnect the antenna and ground. If this doesn't cause much decrease in volume, the antenna system is defective.

An r.f. or i.f. tube with low emission can cause poor sensitivity, so again it is wise to check tubes first.

There are certain conditions about which you can do nothing, such as seasonal changes in reception, differences between day and night-time reception, or inability of the particular receiver to deliver the expected results, because of its basic design. If you don't recognize these, you may let yourself in for an impossible service job.

8. Poor Selectivity. Here again you must be on your toes, for many complaints of poor selectivity are really cases of station interference or inadequate receiver design for your locality. A set with sufficient selectivity for one locality may be inadequate in another, where there are more local stations. Experience with various types of receivers will soon teach you what to expect.

9. Station Interference. Local conditions determine the amount of station interference. A nearby transmitter will usually cause trouble of this kind, although there are several types of station interference.

Try a shorter antenna and try a wave trap before removing the chassis for further tests or adjustments. Other remedies will be discussed elsewhere in your Course.

10. Intermittent Reception. Any of the external defects which cause noise may also cause *intermittent reception*. You can often isolate a noisy or intermittent contact by pulling on leads, wiggling or pushing on parts,

and tapping on tubes. When you come to the defective part, such movements will cause a definite change in the receiver operation.

When the customer complains of changes in volume when an electric light or other appliance is turned on somewhere in the house, look for a poor ground or no ground at all. It may be necessary to run the ground wire to some other point in the home. (In many universal a.c.-d.c. receivers, a ground cannot be used.) Be sure that a good antenna is used and try reversing the line plug.

In some localities, the power line voltage drops considerably during certain intervals of the day. In industrial localities this occurs during working hours, and in residential districts, it occurs in the early evening. When you find that the customer's complaint is due to this cause, all you can do is suggest that the customer bring the matter to the attention of the local power company.

Effect-to-Cause Reasoning

Practical Importance. You can now see that examining a receiver and its installation as just described will often reveal an external defect and save the time you would otherwise spend in removing the chassis from the cabinet. If the preliminary examination indicates internal trouble, however, we must proceed to localize the trouble.

Effect-to-cause reasoning is a process of reasoning from the observed effect back to its possible cause. If we omit this step, we could now go on to the isolation procedures and would eventually find the trouble. However, we must remember that we are attempting to find the trouble in the shortest possible time, so we should take advantage of effect-to-cause reasoning. A minute or two spent in diagnosing the trouble will frequently provide short-cuts around one or more of the servicing steps shown in Fig. 1. Further, a little reasoning will help you choose the proper technique or test methods for each complaint.

Effect-to-cause reasoning is built up from your knowledge of the purpose of each and every part in a radio and from your knowledge of how a part can fail. By tying together these facts and the observed symptoms, you will soon be able to make use of this step. Experience will thus serve to tie your fundamental-course learning to your practical work.

Effect-to-cause reasoning can successfully be used only if there are enough clues to lead you to the trouble. As you know, there are usually many possible causes for a particular effect or symptom of trouble. While confirming the complaint, you should look for additional clues or information which will narrow down the possible number of causes to a few probabilities or will lead directly to the source of trouble.

In many instances, there will not be enough clues at the beginning of a service job to allow effective use of this step. However, by carrying out another step or two of the trouble-localizing procedure, we will narrow down the possibilities considerably and will eventually reach a point where reasoning can be applied. In other words, although we have shown effect-to-cause reasoning as the third

step in Fig. *1*, this is just the first time you can use it. If you cannot go directly to the trouble, isolate the defective section or stage, then try reasoning again.

When you start your servicing career, you will probably find that effect-to-cause reasoning does not work for you every time. Keep trying to use this step, however, as the ability to use it will come to you with experience. Also, experience will add to your store of clues, as you will soon learn that there are different kinds of hum, noise, etc., each indicating a particular source of trouble.

Now, let's take up a few typical examples to show how reasoning can be applied as a step saver.

COMMON CAUSES OF VARIOUS RECEIVER COMPLAINTS

1. Dead Receiver. There are so many defects which can make a receiver dead that here it is usually wiser to start right away on an isolation technique. Nevertheless, there are certain symptoms associated with a dead receiver which are worth watching for because reasoning can often lead directly from them to the cause of the trouble.

As one example, in an a.c. receiver you may find all tubes except *one* heat up normally, yet the one tube may test good. Since other tubes heat, there must be a break in the wiring to this one socket or a defective socket. A break in any circuit will remove an operating voltage, but a tube will become slightly warm if only the filament voltage is applied, so a completely cold tube indicates a filament circuit break.

As another example, you may find all tubes cold in a dead universal receiver. Remembering that tube filaments are in series in universal receivers, you logically check filament

circuit continuity (assuming you have tested the tubes and found them to be good).

2. Noisy Reception. The possible causes for noise are so numerous that here again it is best to start immediately with isolation procedures.

Of course, you should watch for obvious indications such as variations in a tuning indicator or visible sparking which may lead toward the trouble. Likewise, if the noise becomes

When the noise is loudest as the tuning knob is rotated, effect-to-cause reasoning indicates dust or metal particles between the tuning condenser plates. A pipe cleaner (obtained from a tobacco store) is ideal for cleaning, as shown above. This cleaning is done without removing the condenser from the chassis.

more prominent when a volume control, tone control, switch or tuning knob is adjusted, you would reason that the part itself is defective and would check it immediately.

3. Annoying Hum. Filter condensers are the first parts to suspect when hum is the complaint, because their chief job is suppression of hum. An electrolytic condenser which is open, has lost capacity or has a high internal resistance due to drying out will be less effective in reducing the power pack ripple voltage. Shunting each suspect with a good condenser is a quick check for any condenser troubles except leakage or short circuits.

The output filter condenser has more to do with hum than the input one, so it should be suspected first. As additional clues, an open output

filter condenser may result in motor-boating (oscillation or squealing), and there may be a loss in the low-frequency response (a form of distortion).

A defective electrolytic should be completely disconnected when discovered. Never connect a good condenser permanently across a bad one, even though this clears up the trouble at the time, because the bad unit may eventually break down and short the power supply.

You have learned that the input filter condenser builds up the d.c. voltage to a value near the peak value, in addition to reducing the a.c. ripple. Therefore, an open or low-capacity input filter condenser would result in low d.c. voltage and excessive hum. Also, a *leaky* output filter condenser will draw excessive current through the choke coil, which results in excessive hum and a drop in d.c. voltage. Hence, hum coupled with low d.c. voltage is a double clue to filter condenser trouble.

Notice how the basic theory you studied in the Fundamental Course is being put to use in finding the cause of trouble. Just reasoning from your knowledge of circuit and part actions this way will frequently lead right to the source of trouble.

Continuing with our reasoning, an open bypass condenser in an R-C filter for a tube may allow power pack ripple currents to enter the tube stage and produce hum. If a control grid circuit is open, the high input resistance allows small hum currents to set up large hum voltages which the tube will amplify. An isolation procedure will save time in locating these troubles.

If you can hear the hum only when a station is tuned in, the hum must be originating in the r.f. section of the set or at the broadcast station. Obviously, if the hum originates in the audio amplifier it will be heard all the time, whether or not a station is tuned in, as it will pass directly through this amplifier. Hum originating in the r.f. amplifier is called modulation hum, as it travels through the set by modulating an incoming carrier. Tune in several stations to see if the hum comes in with every carrier. If the hum is heard on only one station, the trouble could be in the station itself. You can try picking up the signal from this station on another receiver, but be sure this set is capable of reproducing the low hum frequencies, as not all sets can do this.

If the trouble is modulation hum, we have automatically localized the trouble to the r.f. section, so we can concentrate on locating the defective stage, circuit or part. Notice that the opposite is also true; if hum is heard all the time, it must originate in the audio section or power supply. Again, reasoning has led us directly toward the trouble and has helped prevent blind, unnecessary checking of parts.

The ability to use effect-to-cause reasoning will grow as you gain practical experience. Further, you will begin to notice how different sources of hum and distortion produce characteristic sounds. On your first repair jobs, concentrate on remembering what you hear and find to be the cause of the trouble. Then, in the future, a particular sound or action will bring to mind a particular defect.

4. Squealing or Howling. Since oscillation can occur in any section of a receiver, the first step should be one of making a section isolating test before applying effect-to-cause reasoning.

A simple test will determine whether the trouble is in the a.f. or r.f. section. If tuning of the receiver has no effect on the squeal, and if pulling out the last i.f. tube does not

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stop the squeal, you can definitely say that it is originating in the second detector or a.f. amplifier.

With the trouble isolated to the a.f. amplifier, a put-put sound (motorboating) indicates a low-frequency oscillation and leads you to suspect an open filter condenser, either in the power pack or an a.f. stage.

In the case of a high-pitched squeal originating in the a.f. amplifier, suspect an open plate bypass condenser for the output stage. This condenser is put in the circuit to make the plate load capacitive, thus preventing oscillations.

You learned that a squeal in the r.f. or i.f. sections can be produced only by two signals which differ in value by an audio frequency. Thus, a single stage may go into self-oscillation, producing a signal *which combines with the incoming signal* to produce the audio frequency squeals or a motorboating sound. Also, two stages may be oscillating at the same time, at frequencies which differ by an audio value. This produces a squeal which will be heard even when no stations are tuned in.

Therefore, when a squeal is isolated to the r.f. system, reasoning would lead you to try isolating the defective stage by bringing your hand near each r.f. tube in turn. When the pitch of the squeal changes or the frequency of the "put-put" sound varies as you approach a particular tube, you have very likely localized the trouble to that stage. Remember, however, that bringing your hand near the oscillator stage in a superheterodyne will shift its frequency, thus detuning the set and causing a change in the pitch of the squeal. Disregard this indication.

The first thing you would question in an oscillating r.f. stage is an open screen grid bypass condenser or an open screen grid-to-cathode bleeder resistor. An open bypass condenser destroys the shielding action of the screen grid, while an open bleeder resistor raises the screen grid voltage to the point where the stage becomes unstable.

Reasoning also indicates that an open output filter condenser in the power pack can cause either degeneration or regeneration, depending upon the number of stages in the receiver and the method of coupling the stages. This condenser may therefore be questioned, but beyond this point it is best to begin a more positive isolation procedure.

5. Distortion. You have learned that distortion is most commonly caused by a defect in the a.f. system, so you would first check all a.f. tubes.

Distortion in the loudspeaker is usually easy to recognize. Thus, when the voice coil rubs against the pole pieces, only the higher audio frequencies are properly reproduced. Low notes, which require large movements of the voice coil, sound fuzzy or otherwise distorted. Other loudspeaker defects and their symptoms are considered elsewhere in the Course.

Gassy a.f. amplifier tubes (especially output tubes) and leaky a.f. coupling condensers are so often encountered when distortion is the complaint that they should come to mind immediately. To check these possibilities quickly, measure the d.c. voltage drop across the grid resistor. If the grid end of this resistor is positive with respect to the chassis end, pull out the following a.f. tube, leaving the receiver turned on. If the voltage still exists, you know the condenser is leaky; if the voltage drops to zero when the tube is pulled out, the tube is gassy and was drawing grid current through the grid resistor to produce the voltage drop across it.

Of course, in universal a.c.-d.c. re-

ceivers the tube cannot be pulled out, because this would open the filament circuits for all tubes. Instead, when you encounter a positive voltage across the grid resistor, unsolder one lead of the coupling condenser. If the

In a case of distortion, effect-to-cause reasoning has led this Radiotrician to check the voltage across a grid resistor. By locating the coupling condenser, this measurement can be made between the chassis and the end of the condenser which connects to the grid of the next stage, as shown here.

voltage is still there, you know the tube is gassy; if the grid resistor voltage drops to zero when the coupling condenser is disconnected, the condenser is leaky.

If these preliminary tests fail to reveal the defect, it is time to begin the defective stage isolation procedure for distortion.

6. Low Volume. Suppose you find that volume is low both for local and distant stations. The presence of distant stations shows normal sensitivity. Therefore, you would normally suspect a defect somewhere in the audio system. If the receiver has a tuning indicator which shows the expected variations when a station is tuned in, you have another indication of normal sensitivity. As low-emission tubes are a likely source of trouble, you would check them, if you

have not done so in a surface analysis.

Combination defects give you clues that guide you more definitely. For example, if low volume is associated with a high-pitched tone (little or no bass), you can reason that an open in an a.f. coupling condenser is lowering the coupling capacity so much that only the higher audio frequency can get through. You would then check the coupling condensers before starting isolation procedures. As a rule, however, immediate adoption of a suitable stage isolating technique is best for low volume complaints.

7. Poor Sensitivity. When distant stations are not picked up, the symptom is poor sensitivity. Even local stations may not come in with normal volume if the sensitivity has dropped greatly. If there is a tuning indicator on the set, it can be quite helpful. In case of low sensitivity there will be little or no indication from a tuning indicator when stations are tuned in.

Poor sensitivity is always an r.f. trouble, so you can concentrate on the r.f. amplifier and its tubes. The tubes should be tested first of all.

Poor sensitivity, accompanied by considerable hissing noise, indicates that r.f. gain exists but that little signal is reaching the input of the set. This observation would at once suggest that you check the primary of the antenna transformer with an ohmmeter to see if the primary is open, because this would prevent the signal from entering the receiver. Lightning discharges quite often open the primary and cause this trouble.

Improper alignment will cause poor sensitivity, as all stages will not be properly adjusted to give maximum response to the incoming signal. If stations come in at the proper dial settings, you know that oscillator trimmers are all right. Effect-to-cause reasoning here would lead you

to check only preselector and i.f. trimmer settings. If you find the trimmers badly out of adjustment or that stations do not come in at the correct dial settings, complete realignment of the entire receiver is required.

When poor sensitivity is accompanied by hum, check the filter condensers for an open by shunting with a good condenser. An open input filter condenser lowers operating voltages, while an open output condenser can cause degeneration, both causing poor sensitivity.

Open bypass condensers are possible causes of poor sensitivity, but there are so many of these condensers that it is usually best to start an isolation procedure. Then, when you have found the defective stage, you can check the relatively few condensers in it.

8. Poor Selectivity. First, determine whether the trouble is poor selectivity or station interference. If the interfering station is on the *same* frequency as the desired station, you have station interference. Also, if the interfering station is more than 40 kc. away from the desired station, the trouble is station interference, as the tuned circuits would remove any such interfering signals under ordinary conditions. It is only when the interference is from a station or stations *on adjacent* channels that the selectivity of the set can be questioned.

Next, some judgment is necessary in deciding if the complaint is actually due to a receiver defect or if it is caused by local conditions. The use of an excessively long antenna, or local stations assigned frequencies too close together for the particular receiver design, may cause the selectivity to appear worse than it actually is.

In actual cases of poor selectivity, something is wrong with the tuned circuits. Here the first thing to do is to check the alignment. This will either correct the trouble or will suggest further tests.

If one particular trimmer will not peak or peaks very broadly, you know that trouble exists in that tuned circuit. If the trimmer peaks broadly, you know that the Q of the circuit is low and you should look for high-resistance leakage paths across the tuned circuit. Also, look for resistance in the circuit itself, caused by poorly soldered connections. If the trimmer is in a preselector circuit, the resistance may be due to defective or dirty wiping contacts on the condenser gang rotor sections.

If the dial pointer slips, you will not be able to adjust the trimmers to resonance at the new dial setting. In such a case, reset the pointer before realigning. Also, look for incorrect spacing between the rotor and stator plates of the gang section. If the spacing is not correct, the capacity will be abnormally high, and it will be impossible to reduce the capacity of the trimmer enough to give resonance at the proper dial setting. In addition, one or more turns on a tuning coil may short-circuit, reducing the inductance and making necessary a greater increase in capacity than the trimmer can supply.

In the alignment procedure, the trimmer condensers are adjusted one at a time and the observed reaction to each adjustment serves to isolate the defective stage. Of course, if the trimmer adjustment clears up the trouble, the circuit was out of alignment and no other defect exists.

9. Station Interference. Here, effect-to-cause reasoning plays a very important part in determining the correct cure. If a code station is heard all over the dial, you are safe in assuming that it is operating at the same frequency as the i.f. frequency

of the set, or is at one-half this frequency so the second harmonic of the code station produced by the frequency converter will travel through the i.f. amplifier. Shifting the frequency of the i.f. amplifier 5 or 10 kc. will usually clear this up. In addition, the use of a wave trap tuned to the frequency of the interfering station could be used.

In some cases a squeal will be heard at the dial setting for a favorite station, but is not heard on other local stations. This is usually due to a harmonic of the i.f. getting back into the mixer input and beating with the desired station to produce the squeal. You can't change the station frequency but you can shift the i.f. value of the receiver a few kc. to make the squeal fall to one side or the other of the desired station. In some localities, such troubles are never encountered, while in others the station frequency allocations result in numerous service jobs of this type.

If the interference is from another station on the same frequency, nothing can be done except experiment with different antennas to try to cut down the interference or raise the desired signal strength so it will drown it out. No guarantee can be given beforehand that this procedure will work.

Inexpensive midgets frequently do not have this trouble; their sensitivity is too low to pick up the distant interfering station. If the customer should compare the operation of a midget and another set, you may have to do some careful explaining to satisfy the customer that his large set is working normally.

10. Intermittent Reception If a radio receiver becomes weak or simply goes dead at intervals, effect-to-cause reasoning tells us that practically any part may have failed. An isolation procedure is first employed to localize the trouble as much as possible.

In some instances, the intermittent condition does not take the form of weak reception or a dead set; instead there may be hum, distortion or perhaps squealing at irregular intervals. Here, effect-to-cause reasoning is a powerful tool, as you may be able to determine what part could cause the particular symptom to occur. The same method of reasoning already described for these symptoms is then applied, bearing in mind, of course, that the defect must be such that it can occur intermittently. Because of its construction, an electrolytic condenser would not be likely to open and close intermittently and thus cause intermittent hum. However, cathode-to-heater leakage in a tube can be intermittent, as the heater can often move toward the cathode as it heats.

Defective Section and Stage Isolation

There will be many jobs where it is necessary to make more tests in order to localize the trouble. Hence, the professional technique of isolating the defect to a section, stage, circuit and part must be thoroughly understood.

A simple and quick isolation test often goes hand in hand with effect-to-cause reasoning and eliminates the necessity for going through complete isolation procedures. In other words, one or two carefully planned measurements can eliminate a large number of
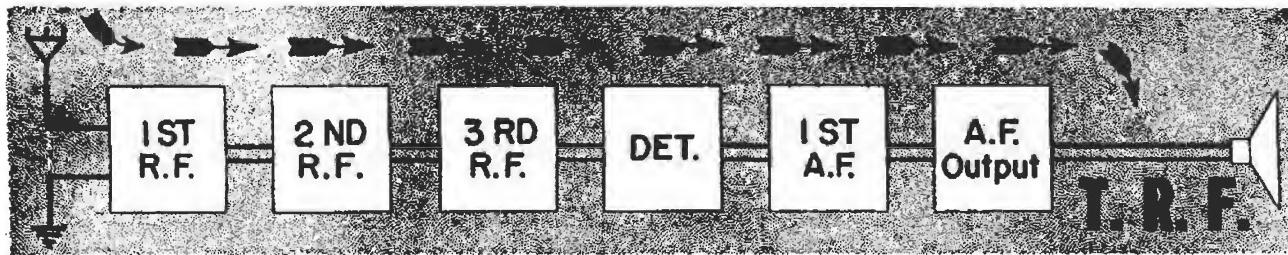
FIG. 2. Block diagram of a t.r.f. receiver.

suspects, thus making isolation easy.

With experience you'll soon develop your own quick isolation tests for different complaints. These tests will essentially be short-cut versions of the complete procedures now to be given. Mastery of these complete isolation procedures is highly essential before you can develop these short-cuts.

The isolation method to use will depend greatly on the conditions encountered and on the test equipment available. The tests you make in the home may be quite different from those made in your shop, yet either type of test will serve to locate the trouble. For instance, you may have a signal tracer or vacuum tube voltmeter in your shop, but you cannot carry this equipment around with you, as it is too delicate or too bulky. Therefore, the tests you make in the customer's home will have to be simple ones—tests that you can make with your multimeter or signal generator, or perhaps with no equipment at all.

Of course, we do not mean that simple tests cannot be used in the shop or that shop tests cannot be used in the home. The best method to use will depend on the complaint, the type of receiver and the available equipment. It is very important to be familiar with all basic methods, so you can choose the proper one for each case. Try all the methods your equipment permits, until you find the best procedure for each complaint.

BASIS FOR ISOLATION TECHNIQUE

All isolation techniques depend upon the simple fact that signals normally travel through vacuum tubes only in one direction. Thus, in tubes having control grids, a signal in the grid circuit can move to the plate circuit, but cannot move in the reverse direction. This is even more true with screen grid tubes, because here the screen grid acts as a shield for any signal which might attempt to go in the reverse direction.

T.R.F. Receiver. The one-way-travel characteristic of signals in a radio receiver can be illustrated by means of the t.r.f. receiver block diagram shown in Fig. 2. Here a signal picked up by the antenna-ground system travels through each stage in turn, finally arriving at the loudspeaker. Under normal conditions the signal never travels in the reverse direction.

The amplitude or strength of the signal will, as a rule, be increased by each stage and will be greater in the plate circuit of a stage than in the grid circuit. These facts are of prime importance in trouble-isolating techniques.

Although we think of noises or howling as audio signals, it is possible for these interfering signals to originate in and pass through r.f. stages. This is possible because noise signals can set resonant circuits into natural oscillation, and the r.f. signal created in this manner will be modulated by the noise. The important point to

remember is that the noise signal will not pass from its point of origin back toward the antenna, and that the stages in this direction will be free from noise.

Hum signals get through r.f. stages in a different manner. If the r.f. stage is operating over a non-linear portion of its dynamic characteristic and a hum voltage is present, the hum voltage will be added to the incoming modulated carrier signal. Of course, the hum modulated signal moves along toward the loudspeaker, not in the reverse direction toward the antenna. This means that stages ahead of the point where the hum modulation took place will have the original hum-free signal.

Superheterodyne Receiver. When the additional signal transformations taking place in a superheterodyne circuit are clearly understood, isolation techniques can be applied just as easily as in a t.r.f circuit. In a super, we still have our signals traveling in a forward direction toward the loudspeaker at all times, as shown in Fig. 3. Neither the desired input signal nor any undesired signals originating in the r.f. amplifier (preselector) can be forwarded through the i.f. amplifier with full strength if the local oscillator is dead or badly

misaligned. Some signals near the i.f. value may force themselves through the i.f. amplifier due to their initial strength, but these will be quite weak at the output because the i.f. amplifier is adjusted to pass with maximum gain only signals at the i.f. value.

In servicing a superheterodyne receiver, your test equipment must naturally be able to produce or detect signals at the i.f. value as well as at the other frequencies which exist in the receiver.

► We will now cover the basic methods of isolating the defective section and the defective stage, leaving circuit and part isolation for another lesson. Further, more complete details on using these methods will be given as the various complaints are covered elsewhere.

DEFECTIVE SECTION ISOLATION

Isolation of the defective section breaks the receiver into at least three parts, the r.f. section, the a.f. section, and the power supply.* This procedure reduces the number of stages which must be checked, and narrows down the possible sources of trouble

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* The r.f. section of a superheterodyne includes everything before the second detector, such as the i.f. stages, first detector, oscillator and preselector stages.
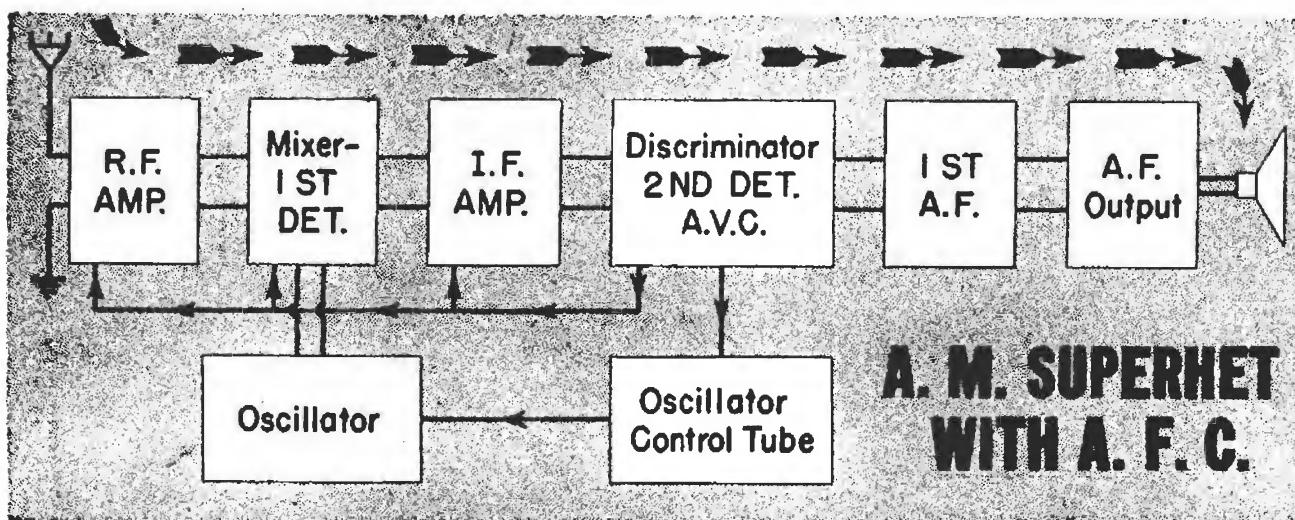

FIG. 3. Block diagram of a superheterodyne receiver having a.v.c. and a.f.c.

The symptom may indicate the section directly, or using effect-to-cause reasoning may lead directly to the defective section. For example, distortion is normally an audio trouble, while modulation hum is an r.f. problem. If the receiver works on one or more bands but not on others, the trouble must be in the preselector or oscillator circuits of the inoperative band, etc. However, if the trouble does not suggest which section is defective, isolation frequently can be accomplished by such simple acts as rotating the tuning or volume controls, pulling out a tube, or touching a grid cap.

If noise or oscillation is the complaint, pulling out the last i.f. tube or the detector tube will determine whether the trouble is in the r.f. or a.f. amplifier; if the noise or squeal disappears, it originates in the r.f. section. Tuning the receiver will determine if modulation hum is present; hum heard only when a station is tuned in originates in the r.f. section.

The volume control will either vary the sensitivity of the r.f. section or will be at the input of the a.f. amplifier in a modern set. Hence, if the control reduces hum, noise or squeals when rotated toward minimum volume, an r.f. trouble is usually indicated. Otherwise, the trouble is in the audio section. Remember, however, that the control itself may develop a poor contact or an open and thus may be the source of noise or cause hum.

When a receiver has a tuning indicator, its action will frequently enable you to identify the defective section. If the set is dead and the tuning eye does not have a green glow, there usually is a defect in the power supply. If the tuning indicator works normally when you tune in a signal,

the r.f. section, second detector, a.v.c., and the power supply are in good condition. This definitely places the defect in the audio section. If the indicator does not have normal action, you know that the r.f. section or the detector is not handling the signal properly. If the complaint is intermittent reception, watch for variations in the tuning indicator when the fading occurs; any variations indicate an r.f. trouble. Sometimes noise or oscillations can be localized by watching for variations. However, remember that power supply variations may change the tuning meter indication.

If the set does not have a tuning indicator, it is sometimes desirable to connect across the diode load a high-resistance d.c. voltmeter (5000 ohms per volt or higher, using the highest range which gives a noticeable deflection). The voltmeter will act like a tuning indicator when the receiver is tuned to a local station, if the sections ahead are working right. In the case of a triode or pentode detector having a plate load resistor, a measurement of the d.c. voltage between plate and cathode will give this same information, because this voltage will change as a station is tuned in if the detector and all preceding stages are intact.

DEFECTIVE STAGE ISOLATION

Signals travel from the input toward the output until the path is interrupted by some defect. Also, if noise, hum, distortion or oscillation occurs, the symptom will start at some point and will become a part of the incoming signal or will send through a signal voltage of its own. Therefore, if we have some instrument available with which to follow the signal along, stage by stage, we will come to the point where the break exists, where the noise, hum or oscil-

lation first appears, or where the distortion takes place. We will thus have located the defective stage.

We can go in the reverse direction also, by introducing a signal of the proper kind, such as from a signal generator or by a circuit disturbance. As the signal source is moved along from the output toward the antenna, the signal will come through normally as long as the stages between the loudspeaker and point of signal injection are working properly. As we move along, the disappearance of the signal or the appearance of the hum, squeal or distortion along with the signal will point to the defective stage.

If the trouble is hum, a squeal or noise which comes through the set even with no signal tuned in, we can use a stage interruption or blocking procedure to localize the trouble. The important facts about these tests will be explained now; later we will learn how to apply them for various receiver complaints.

Circuit Disturbance Method.
For a dead receiver, the simplest stage isolation method is the circuit disturbance test. This test depends upon the fact that any abrupt change in plate current, whether it be a rise or fall, creates a so-called surge signal which is relayed through following stages to the loudspeaker, and there produces an audible click or other indication.

The surges which produce indications in this test can be created by *disturbing* the circuit in various ways, hence this test is called the *circuit disturbance* test.

A surge introduced into the r.f. or i.f. section of a superheterodyne receiver will cause the resonant circuits to be shocked into momentary oscillation at the resonant frequency, producing an r.f. signal which carries the surge signal through the circuit. A disturbance introduced into an audio amplifier is a complex audio signal or noise impulse which travels by itself through the following audio stages.

The necessary disturbance can be introduced in a number of ways. For example, pulling a tube out of its socket cuts off plate current suddenly, creating the required surge or disturbance. Reinserting a tube in its socket causes a sharp rise in plate current, and again a surge is created.

Tubes cannot be pulled out for this purpose in universal receivers, however, because all tube filaments are in series. Also, in some battery sets, removal of one tube may make filament voltages of other tubes too high and possibly cause burn-outs. The following alternative methods of introducing disturbances can be used in these cases as well as in standard a.c. receivers.

Opening a grid circuit by removing the top-cap connection usually makes the grid take on a high negative charge which sharply lowers plate current and creates a surge or disturbance. Putting the top-cap connection back on a tube brings the plate current sharply to normal, again creating a surge.

If the tube does not have a top cap, the control grid can be momentarily shorted to the tube cathode with a test lead. This removes the bias, causing a sharp change in the plate current. Remember, touch these terminals just long enough to get an indication.

Touching the grid lead at the socket, shorting the rotor and stator plates of a variable condenser, or touching a tube top cap is sometimes sufficient to create a disturbance.

Stage Interruption Method.
For locating hum, noise or oscillation, the stage interruption method will prove very helpful. The procedure is basically similar to the circuit dis-

turbance test; however, we are now interested in blocking the circuit, not introducing a surge. Therefore, we can move in either direction, although it is customary to start at the output and work back toward the antenna. As we pull out tubes, the hum or noise will stop as long as it originates further back toward the input. When we pull out a tube and find the noise or hum remains, the trouble is in the last stage interrupted, that is, the next stage toward the loudspeaker.

In universal and battery receivers, it may be impractical to pull out tubes. As an alternative procedure, circuits can be blocked by short-circuiting the control-grid input circuit. In other words, short-circuit the resistor or transformer secondary across which the signal normally appears. If one end of this part connects to chassis or ground, a test lead can be held between the control grid terminal and the chassis. However, if the return end of this part connects to some bias source, it will be necessary to find this terminal, so the test lead can be held right across the part. Otherwise, the test lead may provide a short-circuit path for the bias voltage.

To avoid having to worry about this, a .5-mfd. condenser can be used in place of the test lead. The condenser will bypass signals and thus block the stage without providing a short-circuit path for the bias.

Moving the test lead or condenser along from grid to grid toward the antenna, we will eventually reach a point where the hum, noise or squeal is still heard coming through to the loudspeaker, even while the condenser or test lead is across a grid circuit. The defect is then between this grid and the next grid circuit toward the loudspeaker.

Of course, if the symptom remains when the grid of the output stage is blocked, the trouble is originating in the power supply or output stage. Further, if the intensity of the symptom just decreases instead of disappearing when a stage is blocked, the symptom is either being fed into all stages by way of the power supply, indicating a power supply defect, or it is originating in a prior stage and is being passed around the blocked stage through common power supply coupling.

Signal Tracer Method   Neither the circuit disturbance or circuit blocking methods require that a signal be tuned in. These simple procedures will work satisfactorily only when the defect does not depend on the presence of a signal. Hence, a trouble like distortion or intermittent reception definitely requires that a signal be tuned in before the trouble can be localized. Then, some means of tracing this signal from stage to stage is required. Therefore, with signal tracing equipment, we not only can determine whether signals are coming through; we also can determine the condition of the signal.

Instruments capable of following the signal through the entire radio include r.f. vacuum tube voltmeters, cathode-ray oscilloscopes, and special signal tracing instruments such as the Chanalyst, etc. Although only special instruments such as the Chanalyst are commonly known as "signal tracers," the other devices are used in a similar manner.

To use any kind of signal tracer, we first must have a signal voltage, which may be from a broadcast station or a signal generator. Starting at the antenna and working toward the loudspeaker, we would follow the signal along until it is interrupted or distorted in some manner. This localizes the defect to that particular stage. Similarly, a signal

tracer can be used to run down noise or hum which are also signals.

A defect causing low sensitivity can be found by noting the relative strength of the signal as you progress toward the output. If the signal level does not increase normally in some stage, you have located the defective stage.

Signal Generator Method. The signal generator is a source of voltage, used primarily to align receiver circuits. However, it can be
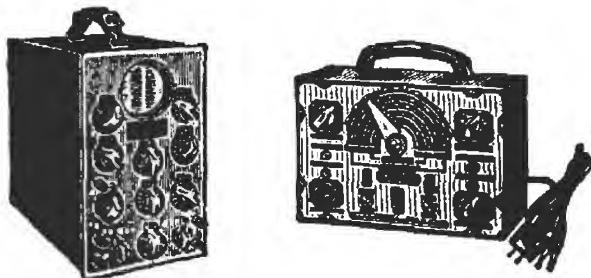
A typical cathode ray oscilloscope and a signal generator.

used for defective stage isolation where the complaint is a dead receiver. The signal generator can also be used to locate certain types of noise and hum which only exist when a signal is present. Further, when used with a cathode-ray oscilloscope, the source of distortion can be discovered.

With the signal generator tone-modulated and adjusted to the proper frequency, we can find the dead stage by starting at the input of the second detector and working back toward the antenna.

If no loudspeaker signal is heard with the s.g. at the second detector input, the trouble is in the audio section. If a signal is heard, work back toward the antenna until the signal stops, showing that you have passed through the defective stage.

Summary. The foregoing description is only intended to make you acquainted with the basic methods

used to localize sources of trouble. When each complaint is taken up later, you will get a more detailed description of these methods. You will learn that some methods work better than others for particular complaints, so you will be shown how to choose the best method for the complaint and your equipment.

Special Receiver Circuits. Any trouble in special circuits like a.v.c. and a.f.c. circuits can be isolated even though these circuits do not amplify or otherwise act directly on incoming signals. A knowledge of how the circuits work and what they produce is essential for any isolation procedure, however.

An a.v.c. circuit produces a d.c. bias voltage which increases in value as the receiver is tuned to resonance with an incoming signal frequency. In some sets, the amount of the a.v.c. voltage is indicated by an electric eye tuning indicator or a meter-type indicator. In sets without visual indicators, you can measure the a.v.c. voltage across the diode load or across individual a.v.c. filter condensers. Use a d.c. voltmeter having a sensitivity of 5000 ohms per volt or higher, since a low-resistance meter will change the circuit resistance and affect the production of a.v.c. voltage. A high-resistance meter will show the changes in a.v.c. voltage which occur as the receiver is tuned to various stations and will determine whether a.v.c. voltage is available for every controlled stage.

Turning now to a.f.c. circuits, we know that when they are working normally, the discriminator output voltage will be alternately positive and negative as the receiver is tuned through a station. At the same time, the volume will remain essentially constant for several kilocycles in either direction from the point at

which the local station should come in.

If the correct variation in voltage is obtained at the discriminator but there is no station-holding action as you tune to either side of the correct setting, a defect in the oscillator control circuit is indicated.

F.M. Receivers. Trouble in f.m. receivers is traced the same way as in a.m. receivers. The incoming signal passes through all of the stages in exactly the same way as in an a.m. superheterodyne receiver. The only major differences are the use of limiter and discriminator stages as last i.f. and detector respectively, and the fact that the a.v.c. voltage is taken from the limiter stage, because this stage has a d.c. voltage which varies with signal strength.

By feeding into an f.m. receiver a constant-frequency r.f. signal produced by an unmodulated signal generator, you can trace continuity for signals from the antenna through the discriminator stage. By connecting a milliammeter in the plate circuit of the limiter, you can check the limiter saturation level and its ability to maintain almost constant output for all values of r.f. input. By varying the frequency of the r.f. input a certain amount in either direction while a d.c. voltmeter is connected across the discriminator output, you can measure the deviation voltage for a given frequency deviation and thereby determine if the discriminator is working properly. All other circuits in an f.m. receiver can likewise be checked exactly as in a.m. superheterodyne and t.r.f. receivers.

Test Equipment for Signal Tracing

Before going on with the use of isolation procedures for a particular complaint, we should learn something about the special equipment used for this purpose.

The basic test instruments used in radio servicing are the multimeter, the tube tester and the signal generator. In addition to these, we have special instruments, each of which has certain advantages for specific types of trouble-isolating jobs. These include vacuum tube voltmeters, signal tracing instruments and cathode-ray oscilloscopes.

Circuit designs vary considerably in instruments made by different manufacturers, because designers may use different methods for securing the same result. From your standpoint as a Radiotrician, however, you are more interested in the *purpose* of each type of service instrument, the *basic design facts* which affect the use of the instrument, and the *limitations of* various instruments. Only signal tracing equipment will be considered here, as the basic multimeter and tube tester are covered in other lessons.

Signal Generator. This is a dual purpose instrument, necessary for receiver alignment and usable in a number of signal tracing procedures.

A frequently used circuit arrangement is shown in Fig. 4. Tube VT_1 is the r.f. oscillator tube connected to the tank circuit L_1-C_1; coil L_2 provides plate to grid feedback. A band switch SW is provided to change coils L_1 and L_2 when different frequency ranges are required for alignment or signal tracing purposes. Condenser

C_1 is variable, and its dial is calibrated so the instrument can be set to any desired frequency.

VT_2 is the audio oscillator tube; iron-core transformer T is used to provide feedback from the plate to grid circuit. The secondary of T is tuned to resonance by condensers $C5$ and C_9 in series, which are selected to give a resonant frequency somewhere around 400 cycles.

The a.f. tank voltage is divided between condensers C_5 and C_9, the voltage across C_9 being used for test purposes. In the average audio oscillator of this type, you may expect as much as 4 volts audio output.

Modulation is obtained by feeding plate power to the r.f. tube through the primary of transformer T. The audio voltage varies the plate voltage of the r.f. oscillator, resulting in plate modulation. The ohmic value of R_2 governs the percentage of modulation; ordinarily the percentage is set between 30% and 50%.

An unmodulated output is sometimes desired and may be obtained by stopping the a.f. oscillator. This is done by closing switch SW_1.

The r.f. voltage which is developed across coil L_1 is fed to voltage divider C_6-R_4, having values of about 10 mmfd. and 2500 ohms respectively. Since the resistance of R_4 is considerably less than the reactance of C_6 at broadcast band frequencies, even complete shorting of the signal generator output will have little effect on the r.f. oscillator frequency.

A maximum r.f. output of about 1 volt is usually obtained across R_4; lower values are obtained by adjusting this output control.

Condenser C_4 in series with the hot r.f. output lead has a value of about 200 mmfd. It simulates an average receiving antenna, and prevents any d.c. voltage in receiver circuits from being shorted by potentiometer R_4
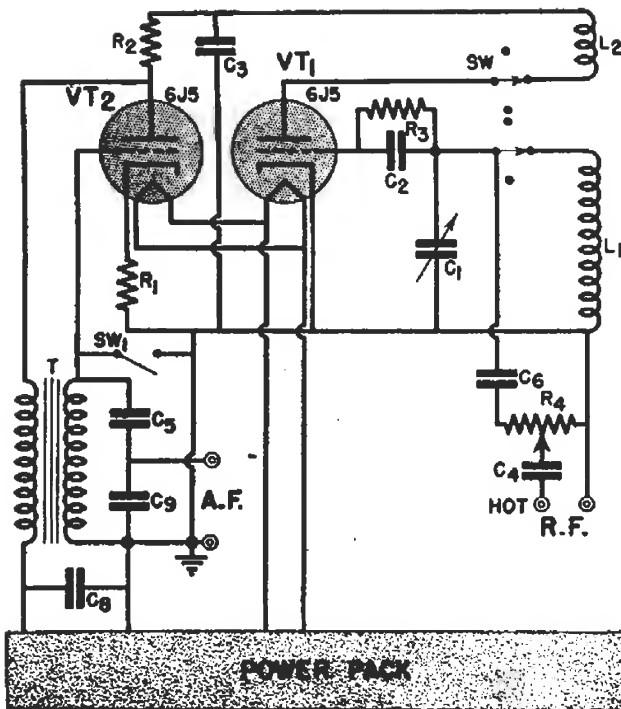
FIG. 4. Functional diagram of a modulated r.f. signal generator, which has separate audio output terminals.

when the signal generator is in use.

In addition to its value in receiver alignment and in isolating a dead stage, a modulated signal generator can be utilized to great advantage for other types of receiver troubles. For example, by connecting a signal generator to a receiver and connecting a cathode-ray oscilloscope to the output, it is possible to analyze various sections of the receiver for distortion and other troubles by studying the output wave form.

R.F. Vacuum Tube Voltmeter. When r.f. signal voltages are to be measured in order to determine accurately the amount of gain or loss in a stage or section, an r.f. vacuum tube voltmeter like the one shown in Fig. 5 is used. Undesirable test lead capacity is eliminated by placing the rectifier tube right in the probe used to pick up the r.f. voltage. The rectifier converts the r.f. into d.c. voltage, which can then be fed through a cable to a d.c. vacuum tube voltmeter.

Standard tubes can be used in the

probe for ordinary service work. However, when an extended frequency range is desired, an acorn-type tube is commonly used. This permits very short leads, making input resonance occur at a very high frequency and reducing the input capacity to a low value, 6 to 10 mmfd. or so. As a result, r.f. voltages up to at least 150 megacycles can be measured with a properly designed r.f. voltmeter.

In Fig. 5, the 955 triode tube is connected as a diode in a shunt-fed

to the input signal flows through the voltage divider resistors. This produces a d.c. voltage drop, so a d.c. vacuum tube voltmeter may now be used to indicate the signal level. The d.c. voltmeter circuit shown in Fig. 5 is of the balanced bridge type, having cathode degeneration to provide a linear scale. The combination R_6-C_2 is an r.f. filter used to keep the r.f. off of the grid of the 6SN7 tube.

Signal Tracing Instruments. An r.f. vacuum tube voltmeter measures every signal (desired or otherwise)
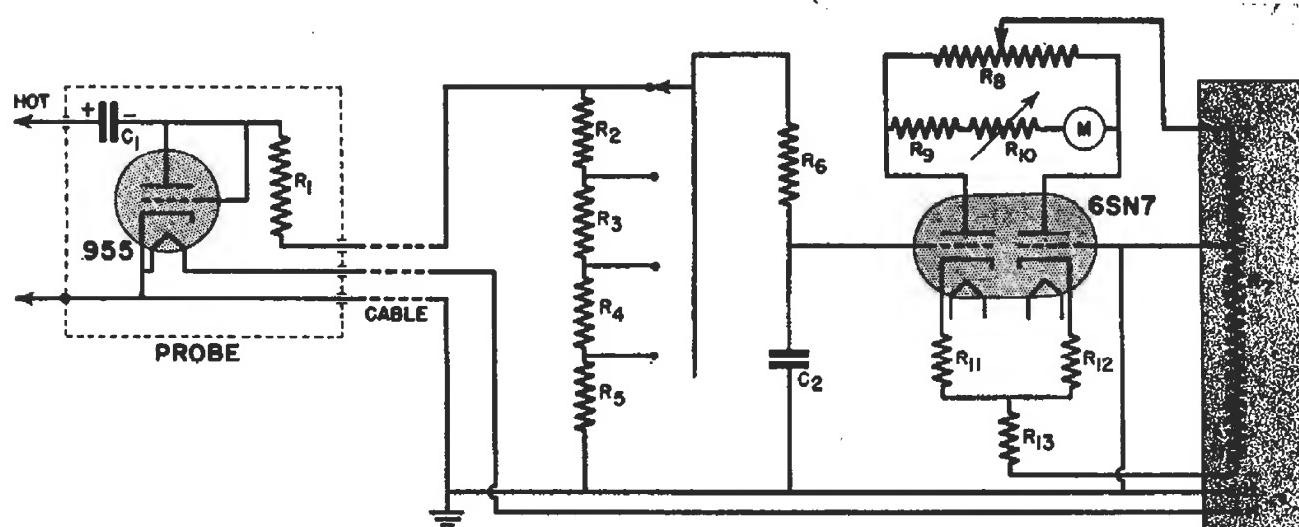
FIG. 5. An r.f. vacuum tube voltmeter capable of covering a wide frequency band without appreciable loading of the voltage source.

rectifier circuit. When an r.f. voltage alternation (half cycle) makes the *HOT* probe positive, electrons flow from the 955 cathode to the plate, charging condenser C_1 to the polarity shown. For the other a.c. alternation, the tube is blocked, and condenser C_1 discharges through resistor R_1 and the voltage divider R_2, R_3, R_4 and R_5. The time constant of C_1 and the resistors is chosen so C_1 discharges only a slight amount during a half cycle. Hence, the diode passes current to recharge C_1 only on the extreme positive peaks of the a.c. cycle, thus negligibly loading the source of voltage.

A d.c. current which is proportional

at the point of connection. A signal tracing instrument eliminates this difficulty by placing a tuned r.f. amplifier ahead of the indicating circuit. Unfortunately, r.f. amplifier gain varies for different frequency settings, so that an indicator in the output could not be accurately calibrated in terms of input voltage, especially if a wide range of frequencies is involved. The chief purpose of a signal tracer of this type is to measure relative changes in signal strength and to indicate the presence of signals of particular frequencies.

The basic circuit for a signal tracing instrument is shown in Fig. 6. We

have a two-stage tuned r.f. amplifier using type 6AC7 or similar tubes, with provisions for band switching. The usual over-all frequency range is from about 90 kc. to about 16 megacycles. Some instruments will have only one r.f. stage, while others may have two or three.

The r.f. amplifier feeds a linearly-operated diode detector whose output may be used for visual or audible signal indication. R.F. and a.f. components in the output of the diode are filtered out, leaving only a d.c. volt-

AMP." in Fig 6 can be connected to a cathode-ray oscilloscope for analysis or to an a.f. amplifier and loudspeaker. Some instruments will have a built-in audio channel, with provisions for connecting a headphone or loudspeaker, while others may have a built-in loudspeaker. With an audio channel, a serviceman can listen for the signal and also hear distortion, hum or noise.

The tuned r.f. amplifier in a signal tracing instrument is designed to give high gain. Each frequency range is
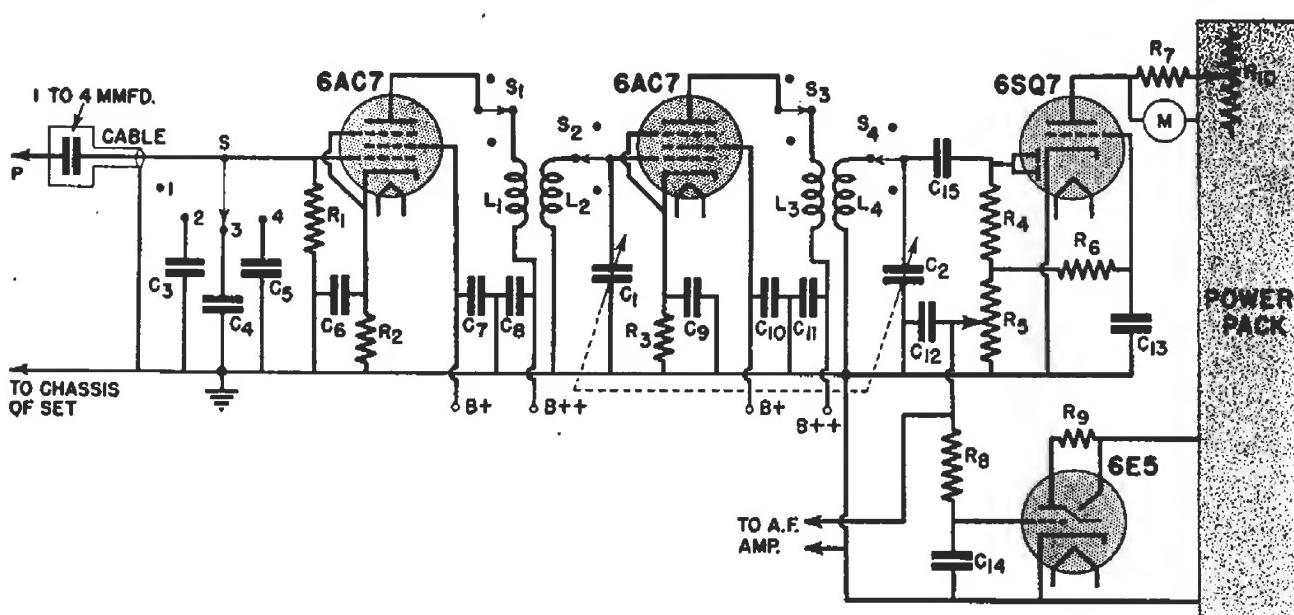
FIG. 6. A fundamental diagram of a multi-band signal-tracing instrument. Coils are shown for only one band.

age proportional to signal strength. This voltage can be used to actuate an electric eye tuning indicator, such as the type 6E5 tube shown.

Another indicating method involves applying the d.c. voltage to a d.c. amplifier (the triode section of the 6SQ7 tube), and using the resulting current to actuate an ordinary meter (M). The normal d.c. plate current of the triode through meter M is canceled out by adjusting potentiometer R_{10} in the power pack. When the adjustment is properly made, the meter deflection is proportional to the carrier input signal strength.

The two leads labeled "TO A.F.

made as uniform as possible, and all bands are designed to have approximately the same gain. Only tuned r.f. amplifiers can be used here, because superheterodyne circuits which might give more uniform gain would introduce so many interfering signals that confusion would arise.

The shielded cable used as the test lead has a small series condenser built in the test probe. This condenser reduces the effect of the cable capacity by acting with it as a capacity voltage divider. This makes the input voltage division constant for frequencies up to about 5 mc. Above this frequency, the shielded cable will begin to upset

the voltage division by starting to act as a resonant line. As most radio service measurements are made below 5 mc., this does not greatly matter.

A capacity voltage divider is used at the input to extend the voltage range. The capacity required is added by switch S.

When an electric eye tuning indicator is employed, tuning condenser C_1 and C_2 are simultaneously adjusted for maximum deflection, and switch S is then set to a position which permits adjusting R_5 so the eye will just barely close. The reading of R_5 is multiplied by the multiplying factor of S to give an indication of the input voltage.

By shifting the probe to another r.f. terminal, tuning C_1 and C_2 to resonance and then adjusting S and R_5 for closure of the electric eye indicator, another value is obtained. Dividing one value by the other gives a ratio corresponding to the voltage gain or loss between the two points. Thus, as you probe from the antenna step by step toward the loudspeaker, greater values should be obtained in a normal receiver.

Regardless of the indicating means, this signal tracer can be used in all the r.f. and i.f. amplifier stages. A separate audio amplifier channel is necessary to work from the second detector to the loudspeaker. This audio channel is usually built into a complete signal tracer, and usually uses the same kind of meter or tuning eye indicator as the r.f. channel. For audio work, the capacitance of the input cable is normally unimportant.

Cathode-Ray Oscilloscope. This instrument makes it possible to see the wave form of the signal at any point in a circuit. In the r.f. and i.f. sections of a receiver, the modulation envelope is studied. In the a.f. sys-

tem, any distortion, ripple current, regeneration, noise and motorboating are clearly evidenced when a pure sine wave audio signal is fed into the receiver circuit.

The functional diagram of a cathode-ray oscilloscope (c.r.o.) is shown in Fig 7. Probe P may be connected directly to a terminal which is hot with respect to the chassis. Any a.c. voltage on this probe causes vertical movement of the dot on the c.r.o. screen. Potentiometer R_1 limits the vertical movement to any desired amount. At the same time, the horizontal sweep circuit moves the spot horizontally; if synchronized with the input signal, it will give a stationary curve.
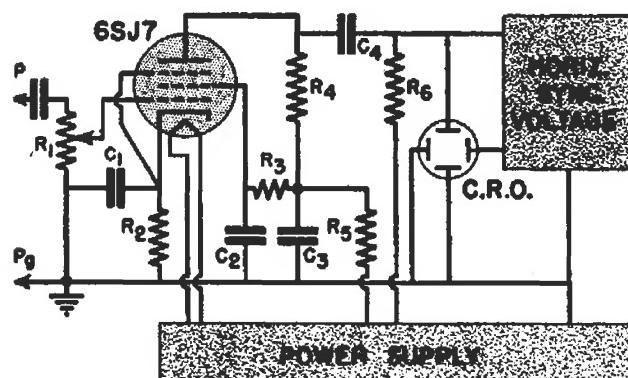

FIG. 7. Basic cathode-ray oscilloscope circuit, used for wave-shape analysis.

Although the oscilloscope usually has sufficient amplification to be used by itself, it can also be connected to the audio output terminals of a signal tracing instrument. Then any r.f. or i.f. stage in a superheterodyne receiver can be analyzed for defects which affect the modulation envelope, provided the input to the receiver is a sine-wave modulated signal from a signal generator. If the modulation frequency is low, about 400 cycles, sharpness of resonance in the test circuit can be ignored, because a highly selective circuit only cuts off (attenuates) the higher audio frequencies.

Isolation Techniques for a Dead Receiver

We will now take up the complaint of a dead receiver and show just how the different isolation techniques can be applied to this complaint. Methods applicable to the various other complaints will be taken up in other lessons.

Whether you should make a section isolation or should go on to a stage isolation procedure will depend on your preferences and experience. Usually, a professional serviceman will go at once to the stage isolation tests when the complaint is "dead set," as the necessary tests can be performed rapidly. We will now take up these methods, starting with the circuit disturbance test.

CIRCUIT DISTURBANCE TEST

To isolate the dead stage by means of the circuit disturbance test, start at the output stage and work backward* toward the antenna terminal, creating in each stage in turn the required surge. If you hear the characteristic click or thud in the loudspeaker as a result of this surge, you can be reasonably sure that the plate circuit of the tube you are disturbing and all following stages are in good enough condition to permit passage of signals.

If no click, thud or howl is heard when a stage is disturbed, you have isolated the defect to that tube, the electrode circuits of that stage, the coupling to the next stage toward the loudspeaker, or the grid circuit of the next stage.

Quite often, touching a grid will set up circuit oscillations which cause a howl instead of a click or thud. Re-

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* Backward is used here to mean in a direction opposite to the normal direction of signal travel.

gardless of the method used to create a disturbance, the indicated click or howl will not be heard in the loudspeaker if a stage between the point of disturbance and the loudspeaker is dead.

The only stages which may not give an indication of some sort when disturbed are a diode detector, a separate a.v.c. tube, an oscillator control tube in an a.f.c. circuit, a tuning indicator tube, and other tubes which are not in signal circuit paths or in the power supply system. The diode detector has no d.c. plate current to be disturbed. However, disturbing the preceding i.f. tube does cause a click to pass through the detector, as the surge is then acting as a signal. No click indicates either a defective last i.f. or defective detector stage, if the audio stages responded properly.

Locating the Defect. Having localized the defect to this extent, you would first test the tube in the section concerned, if you had not already done so. Next would come either a test of electrode voltages or circuit continuity, until you localized the defect to one of the suspected circuits and eventually to a particular part. This will be taken up when we discuss defective circuit and part isolation.

Possible Complications. The circuit disturbance test is admittedly not entirely fool-proof. Conditions can exist which produce confusing indications.

For example, when you have progressed well into the i.f. or r.f. section with a circuit disturbance test, the click or other indication in the loudspeaker may be quite weak if any of the stages between the disturbance

point and the loudspeaker are badly out of resonance (out of alignment). Sometimes it is possible to hear an indication of some sort, even with an actual defect in the chain of stages between the disturbance point and the loudspeaker, because a circuit disturbance can be relayed through the power supply system to the loudspeaker. This case can be recognized with a little experience, as the indication will be unusually weak.

If no click or other indication is heard for the output stage, or if the indications are weak for all stages being disturbed, a loudspeaker or power supply defect is indicated. Measure the output voltage of the power pack or measure the plate or screen grid voltages of the output stage.

In the case of a push-push output stage employing zero bias, no indication will ordinarily be obtained when the control grid is shorted to the cathode. If a disturbance introduced in the preceding a.f. stage is heard, however, you know that the push-push output stage is normal.

Most servicemen start by pulling out the first audio tube instead of the power output tube, particularly when there is only one output tube. This saves a little time, as a satisfactory indication acts as a section isolating test and eliminates the need for an output stage disturbance. Furthermore, there is a possibility that the large surge produced by an output stage disturbance may puncture the insulation in the output transformer or in a filter condenser. This rarely occurs, and then only where the part is already weakened, so perhaps it is just as well that the part be replaced before it fails of its own accord.

SIGNAL GENERATOR TEST FOR A DEAD STAGE

If you apply a test signal between any grid or plate and *the chassis* in a dead receiver, and the loudspeaker reproduces the modulation tone of that signal, you know that the signal path is intact from the signal source to the loudspeaker. This is the basis for an isolation procedure involving a signal generator.

To isolate the dead stage with the aid of a signal generator which has independent a.f. output terminals, you can start at the input of the final a.f. stage and work backward toward the antenna, connecting to the input of each stage in turn and adjusting the signal generator to provide the proper type of signal for each circuit. When you first fail to hear the signal in the loudspeaker, you know that you have just passed through the defective stage.

If the signal generator does not have provisions for separate a.f. output, you can start at the plate of the last i.f. tube, with the signal generator set to the i.f. value. If the signal comes through, the second detector, a.f. stages and loudspeaker are all right; if not, some other isolation procedure must be used on these stages (you can listen to the output of each a.f. stage in turn with headphones which are used in series with a condenser to prevent shorting of the plate supply, or you can use a circuit disturbance test).

A condenser should be in series with the hot signal generator lead, in order to prevent shorting of d.c. electrode voltages by the signal generator when the hot lead is applied to a grid or plate terminal. Most signal generators have a built-in series condenser, but if none is present you can use any condenser value from .001 mfd. to .1 mfd., rated at 600 volts d.c. or higher.

In working from the input of the second detector up to the input of the mixer-first detector, the signal gen-

erator should be adjusted to the i.f. value of the receiver.

The i.f. value will usually be given on the schematic diagram of the receiver; if you do not have a diagram or if the value is not given, connect the s.g. to the grid of the last i.f. tube and sweep its frequency slowly down from 500 kc. to 100 kc. until you get maximum response. The s.g. setting will then be approximately the i.f. value. The correct value will probably be the nearest standard value, such as 175, 265, 370, 455, 465 or 480 kc. If the trimmer condenser adjustments have been tampered with, you may have to realign the i.f. stages as you move along toward the first detector.

After arriving at the input of the first detector and checking passage of the signal at the i.f. value, change the signal generator to a frequency corresponding to the receiver tuning dial setting. A response from the loudspeaker now proves that the local oscillator is working.

The signal generator can now be moved right up to the antenna and ground terminals, for a check of the preselector.

If no signal is heard when you are at the input of the first detector, with the signal generator set at the frequency corresponding to the receiver tuning dial setting, the oscillator is dead or out of alignment. Check the oscillator as follows: Tune the receiver to the frequency of a powerful local station, set the signal generator to the frequency of the local oscillator (to the receiver tuning dial setting plus the i.f. value), remove the signal generator audio modulation if a switch is provided to give unmodulated output, then vary the output frequency of the signal generator a few kilocycles in either direction. If the station is now heard, the defect is in the oscillator stage.

## VACUUM TUBE VOLTMETER TEST FOR A DEAD STAGE

With an r.f. vacuum tube voltmeter, you can check r.f., i.f. and a.f. voltages in both the plate and grid circuits of a dead receiver, and isolate the defective stage by verifying the presence or absence of the signal from a signal generator connected to the receiver input.

With the signal generator set to produce full output, you should be able to start at or near the antenna with the vacuum tube voltmeter, and proceed toward the loudspeaker, stage by stage, until you pass through the stage at which the signal vanishes. The signal will become stronger and stronger as you move toward the loudspeaker, making it necessary to change to less sensitive ranges on the instrument.

With a vacuum tube voltmeter, you must be on guard for conflicting readings due to hum and other undesired signals, which may give meter deflections even when the signal you are tracing does not exist. By tuning the receiver or signal generator slightly away from resonance, or by turning the signal generator off and on each time a test is made, you can determine whether the deflection is due to the desired signal or is due to hum, noise or other signals. The indication will disappear or drop considerably during this test if it is due to the proper signal.

It is necessary to retune any resonant circuit when the v.t.v.m. is connected across it, as the capacity of the device may detune the stage completely so that you get an indication of a dead stage, or may tune the circuit to some other signal. Remember to restore the original trimmer setting when you move on to another circuit.

With a vacuum tube voltmeter, you
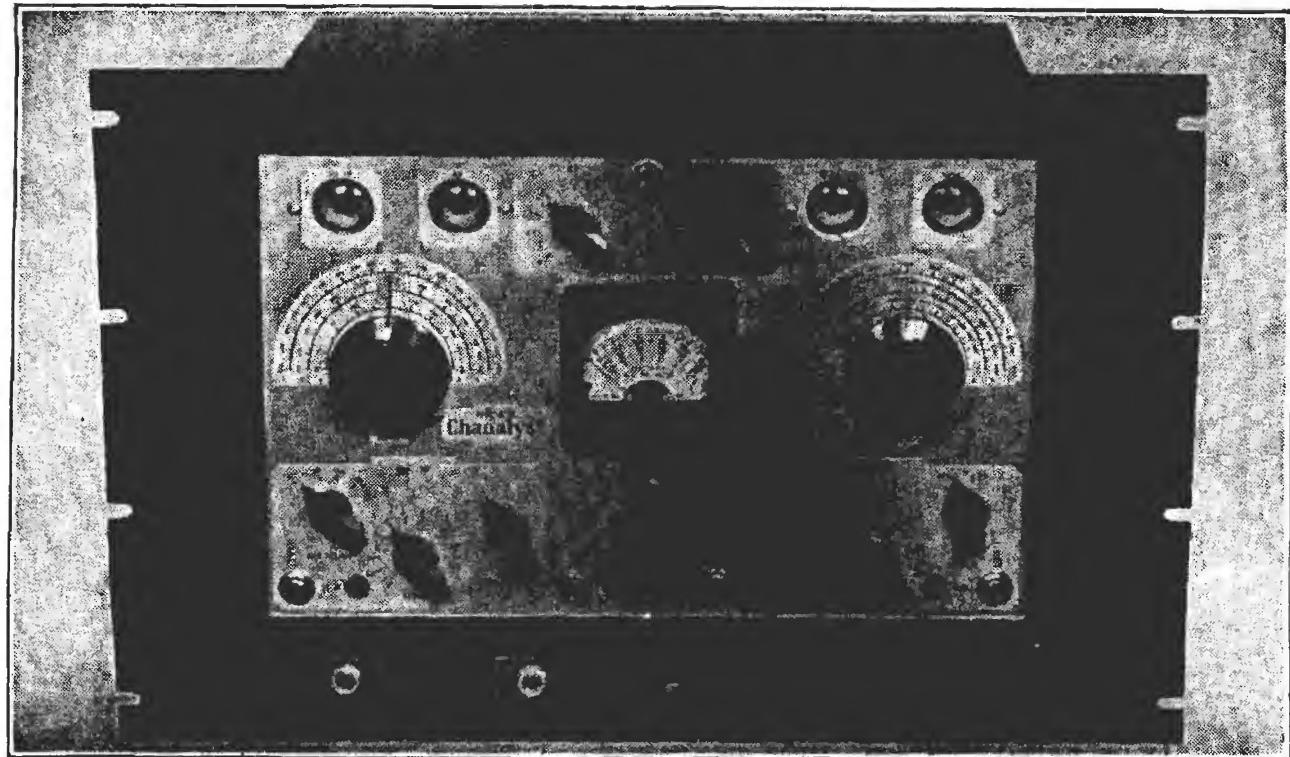
The RCA-Rider Chanalyst uses tuning eyes to indicate the strength of the input to the r.f., a.f., and oscillator channels. Another eye is used as a wattage indicator. The meter is part of a built-in d.c. vacuum tube voltmeter.

can measure the output of the local oscillator directly across its tank circuit. If the instrument is also designed for d.c. measurements, you can connect it across the diode detector load for use as a tuning indicator where the set does not have an indicator. If its reading changes as a station is tuned in, you know that the r.f. system is active, and can concentrate on the a.f. stages.

It should be emphasized that many complications can occur when using a vacuum tube voltmeter, because it does not have a preselector and hence responds to all signal frequencies. This led to the development of signal tracing instruments which do have tuned stages.

SIGNAL TRACING INSTRUMENT TESTS FOR A DEAD STAGE

A signal tracing instrument indicates the presence of signals at a particular frequency. It can be accurately tuned to any frequency which normally exists in a receiver, and can thus be used to determine exactly what frequencies are present in each stage, and their relative strength.

Since the usual signal tracing instrument has a high input impedance, it may be connected between any electrode and the chassis without serious detuning of tuned circuits. The trouble can thus be isolated *to a particular circuit* in the dead stage.

In using a signal tracing instrument to isolate a dead stage, the receiver is connected to an antenna and tuned to a local station, or is connected to a signal generator and both receiver and signal generator are tuned to the same frequency. The ground probe of the signal tracing instrument is then connected to the receiver chassis, and the hot probe is connected in turn to the antenna, the grid of the first r.f. tube, the plate of the first r.f. tube, the grid of the mixer tube, the plate of the mixer tube, the

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grid of the first i.f. tube, the plate of the first i.f. tube, etc., in sequence, working toward the loudspeaker.

In each stage, the signal tracing instrument should be tuned to the resonant frequency of the circuit to which it is connected. For instance, if the receiver is tuned to 1080 kc. and the i.f. value of the receiver is 455 kc., the signal tracing instrument would be tuned to 1080 kc. up to the input of the mixer-first detector. From there up to the input of the second detector, the signal tracer is tuned to 455 kc., corresponding to the i.f. value.

Always tune the signal tracing instrument for maximum output indication. This will either be maximum meter deflection, maximum closure of the electric eye indicator or maximum loudness of the audible signal, depending on the design of the instrument.

In this example, if you do not get a 455-kc. signal at the output of the frequency converter, you can tune the signal tracing instrument to 1080 kc. to see if the input signal is coming through the converter stage. Next, tune the signal tracing instrument to the oscillator frequency of 1080 plus 455, or 1535 kc., to see if the oscillator is working. Both signals will be present in the plate circuit of the first detector but will be weak, as the i.f. tuned circuit rejects these signals. However, they can be ob-

served if everything is normal.

Failure to get a signal of the correct frequency at a particular point in the circuit isolates the defect to that circuit. Then, a circuit continuity test, followed by parts testing, will usually reveal the defect in short order. However, with a signal tracer it is often possible to check and locate the defective part without using other instruments.

An audio channel is necessary to trace from the output of the second detector to the input of the loudspeaker Usually such a channel is provided on the signal tracer.

As you progress toward the loudspeaker with a signal tracing instrument, the signal strength should increase, making it necessary to reduce the gain of the instrument. It should be noted that a great decrease will be observed when going from the primary to the secondary of an output audio transformer, as this is a voltage step-down device. An increase in signal strength will be noted, however, when going from primary to secondary in a step-up audio coupling transformer or in a transformer-coupled r.f. or i.f. stage in which only the secondary is tuned. In passing from a plate circuit to a following grid circuit where R-C coupling or double-tuned transformers are used, a slight decrease in signal strength is normally to be expected due to losses in coupling.

Lesson Questions

Be sure to number your Answer Sheet 37RH-2.

Place your Student Number on *every* Answer Sheet.

Send in your set of answers for this lesson immediately after you finish them, as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.

1. If the pilot lamp does not glow and none of the tubes become warm when an a.c. receiver (not universal) is turned on, what things would you check before removing the chassis? *Broken power cord, faulty plug, no power in wall outlet.*

2. If noise disappears when you short together the antenna and ground terminals of a noisy receiver, is the cause of noise likely to be inside the chassis? *No*

3. Why are felt washers often used between control knobs and the front panel of a receiver? *To minimize mechanical feedback from the cabinet to the set.*

4. When distortion is the complaint in an a.c. receiver, effect-to-cause reasoning indicates that the voltage across grid resistors in resistor-condenser-coupled a.f. stages should be measured. If one grid is positive with respect to the chassis, and this positive voltage still exists when the a.f. tube of that stage is removed without turning off the receiver, which part is defective? *The coupling condenser*

5. When using effect-to-cause reasoning, what symptoms would you expect from an open output filter condenser? *Hum and a loss in low frequency response*

6. State the basic fact upon which all stage-isolating techniques are based.

7. Suppose that you are carrying out a circuit disturbance test for isolating the defective stage in a 7-tube a.c. t.r.f. receiver. You pull out and replace tubes one by one, working from the loudspeaker toward the antenna, and get clicks in the loudspeaker for the a.f. output tube, the first a.f. tube, the detector tube, and the third r.f. tube, but no click for the second r.f. tube and the first r.f. tube. Which stage contains the defect? *The stage between the 2nd & 3rd R.F. tubes.*

8. In making gain measurements with a signal tracing instrument, would you expect an increase in a.f. voltage when going from the primary to the secondary of the output transformer? *No.*

9. Suppose that the i.f. value of a receiver is not given and that you are reasonably sure the i.f. trimmers have not been tampered with. State the procedure that you would follow, using a signal generator, to find the i.f. value. *P 26*

10. What is the advantage of a signal tracer over an r.f. vacuum tube voltmeter? *The signal tracer responds to only the signal it is set for, whereas a r.f.*